

Lead and Copper Research Update: Recent Findings and Future Areas of Work

Darren A. Lytle
U.S. Environmental Protection Agency
ORD, NRMRL, WSWRD, TTEB,
Cincinnati, Ohio 45268

Ohio AWWA Meeting
Sept. 16, 2004
Toledo, Ohio

Acknowledgements

Michael Schock- co-investigator

Jeremy Payne

Joe Feldhaus

Christy Frietch

Tori Blackschlegger

Rachel Copeland

Christy Frietch

Copper and Lead Research Program

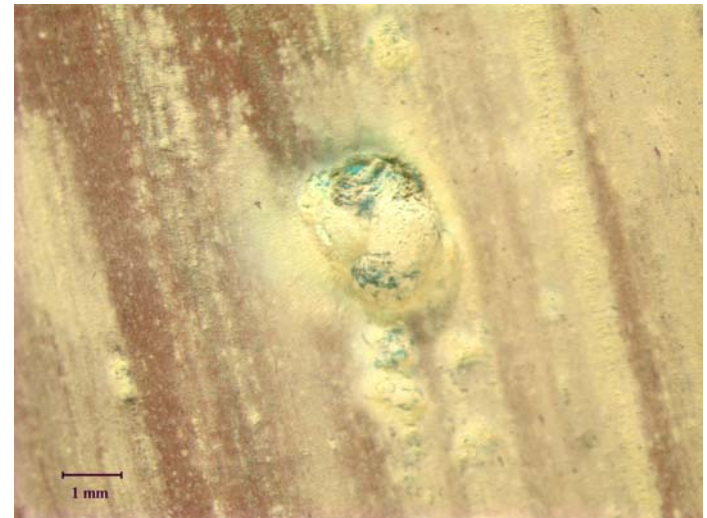
- Non-uniform copper corrosion (pitting)
 - Materials/solids analysis
 - Electrochemical corrosion studies
- Copper
 - Aging
 - High alkalinity
- Lead
 - Pb(II) vs Pb(IV)

Non-Uniform Corrosion

Copper Pitting

Background

- Lead to "pinhole" leaks
- Costly Repairs
- Leaks may go undetected in walls or basements, and service lines
- Pinhole Leaks
 - Mold and Mildew
 - Liability Issues
- Does not lead to high copper levels at the tap



PITTING is a localized acceleration of corrosion that results in the thinning of the pipe wall in the impacted area.

Pinhole Leaks

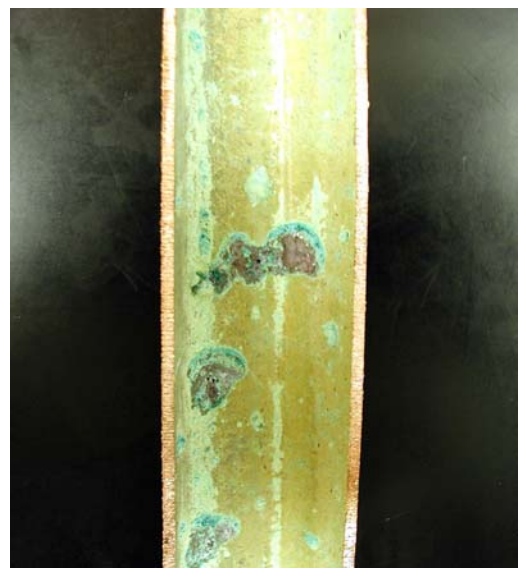


Pinhole leaks resulting from copper pitting

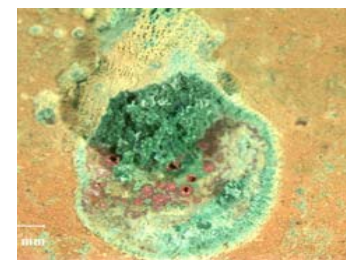
Pitting Is Complicated



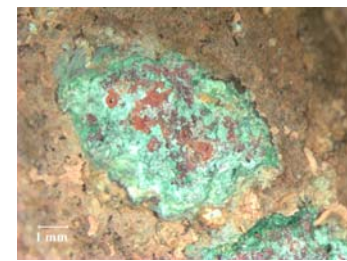
Ohio site #1



Wisconsin



Ohio site #2



All micrographs taken at 10x

Studying a Pitting Problem

Approach

- Field Observations

- Survey Form- plumbing type, cold vs. hot, horizontal, etc..

- Solids Analysis

- SEM, EDS, XRD, etc..

- Water Quality

- Hot vs. cold, similar waters

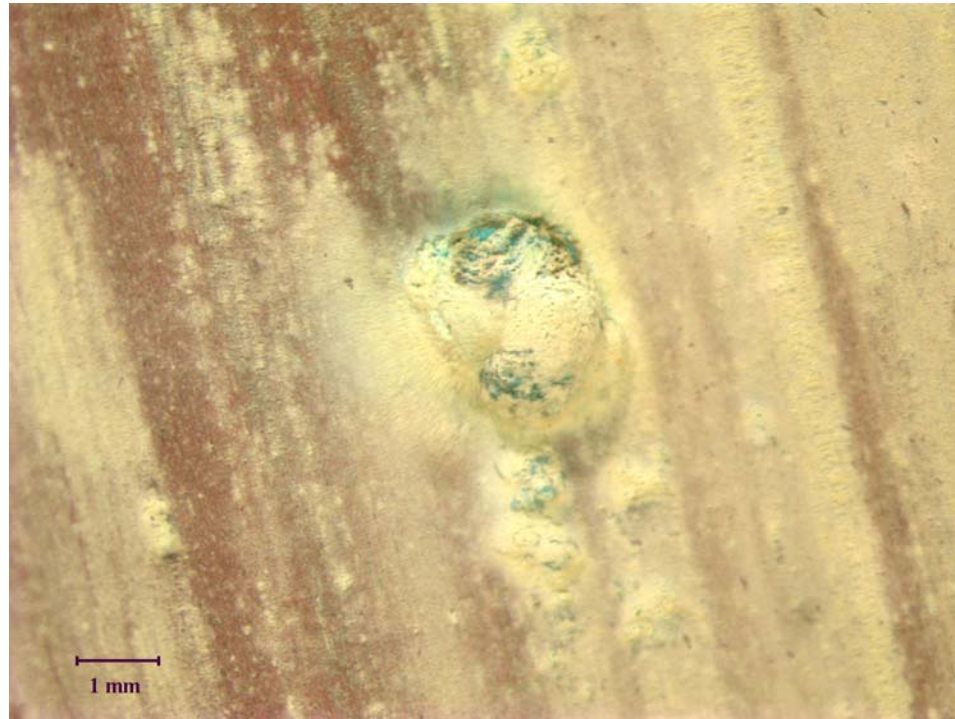
Case Study- Ohio Site

Field Observations

- Cold water
- Horizontal runs of pipe
- $\frac{3}{4}$ " pipe
- Homes are about 7 years old
- Leaks occur near elbows and joints as well as in long runs
- No preference for the top or bottom of a pipe

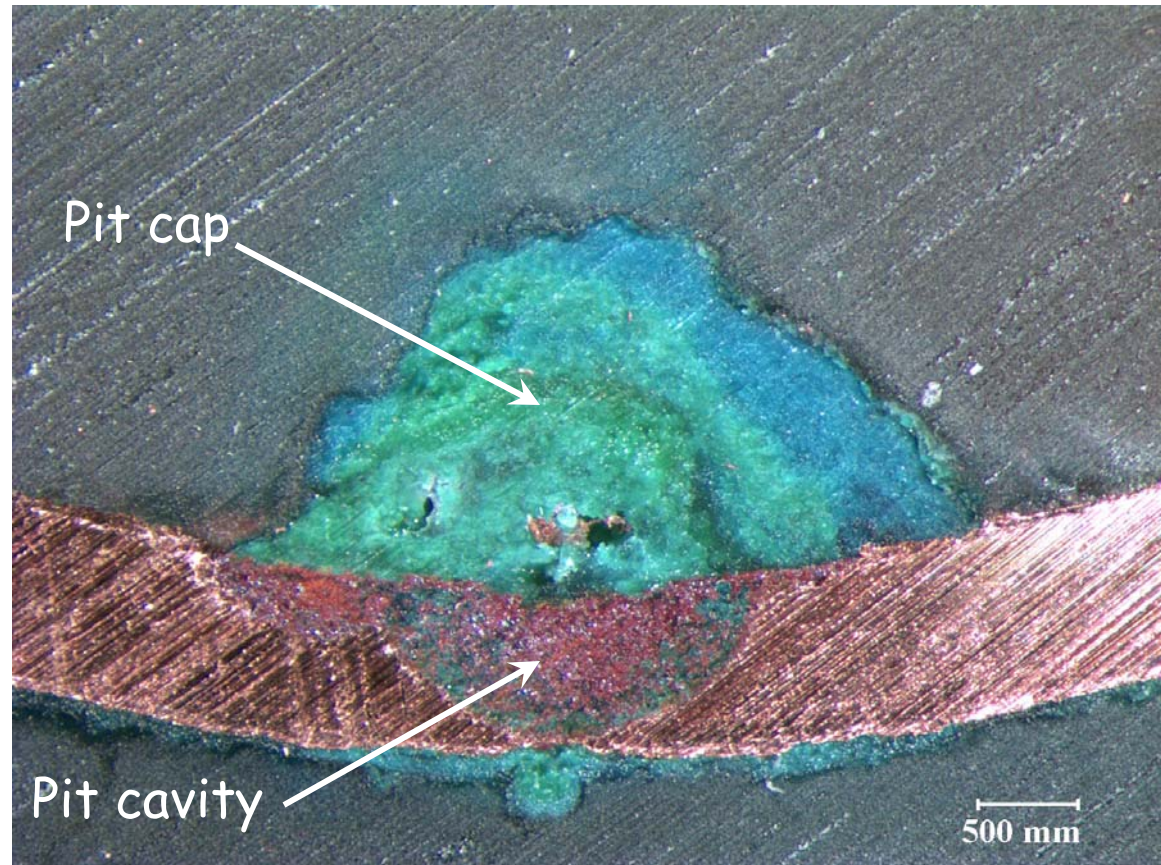
Anatomy of a Pit

Solids Analysis



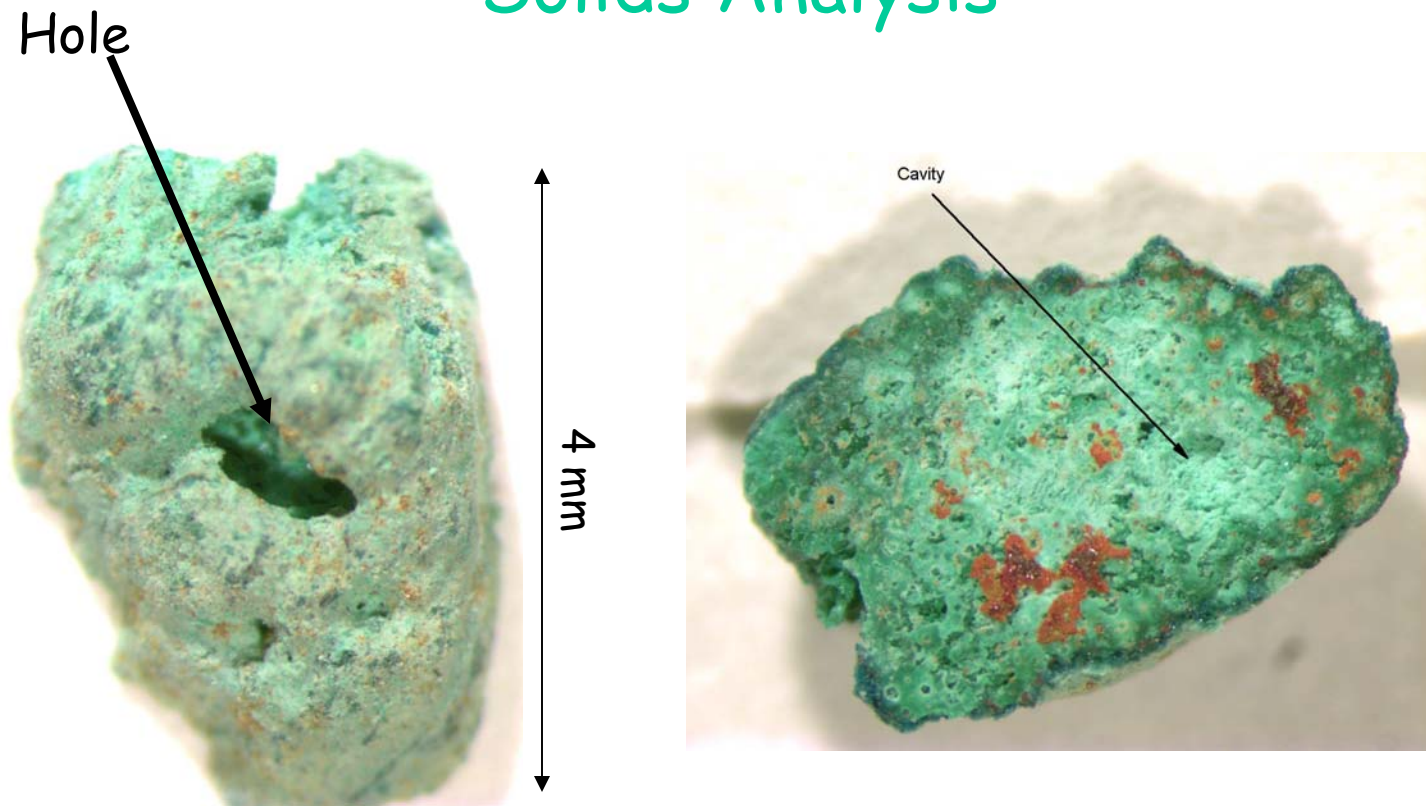
Anatomy of a Pit

Solids Analysis



The Corrosion Cap

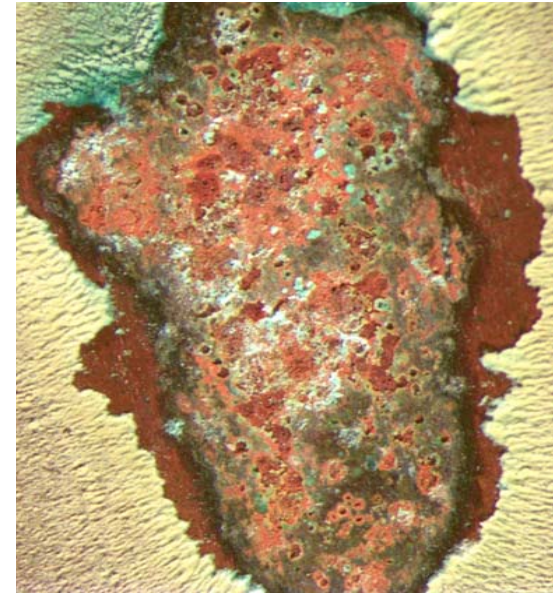
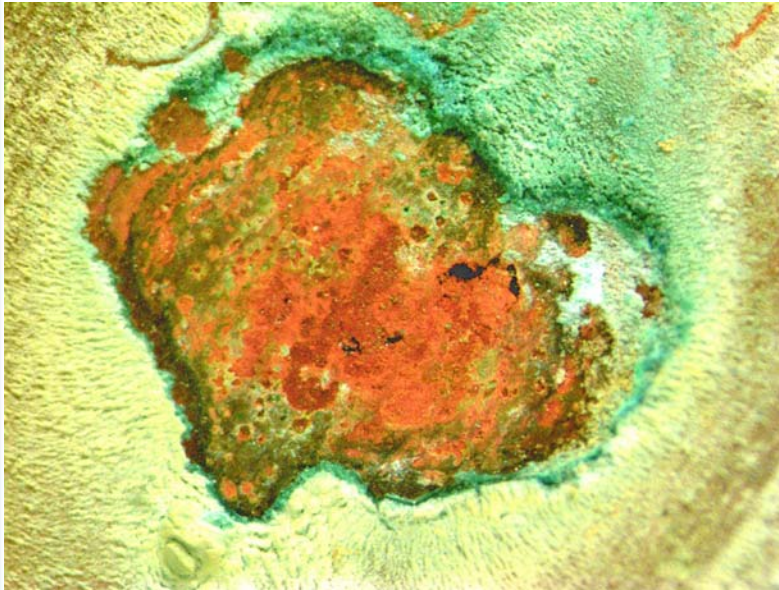
Solids Analysis



Brochantite - $\text{Cu}_4(\text{OH})_6(\text{SO}_4)$
Ponssjakite - $\text{Cu}_4(\text{OH})_6(\text{SO}_4) \cdot \text{H}_2\text{O}$

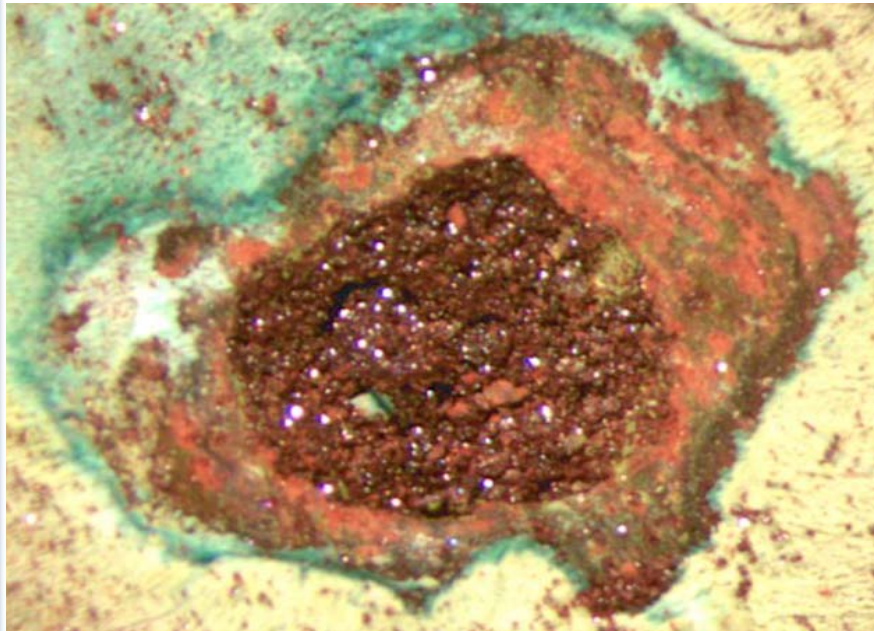
Perforated Membrane

Solids Analysis

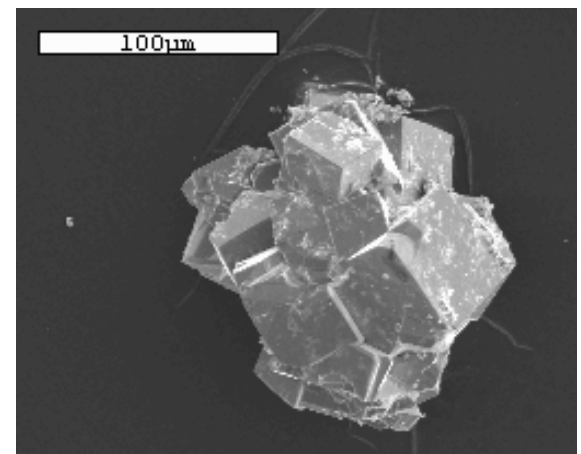
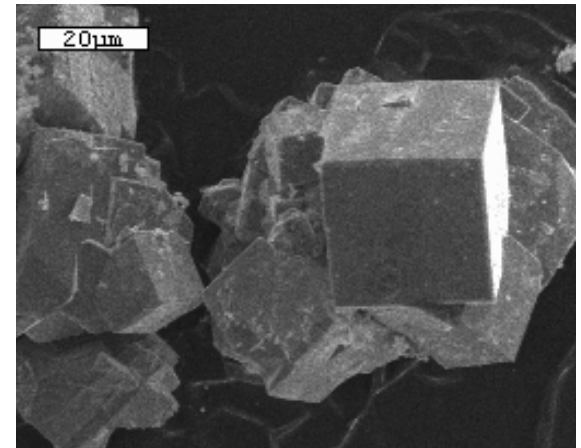


Literature suggests that the membrane consists of cuprite.

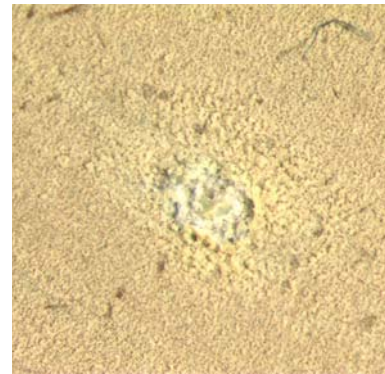
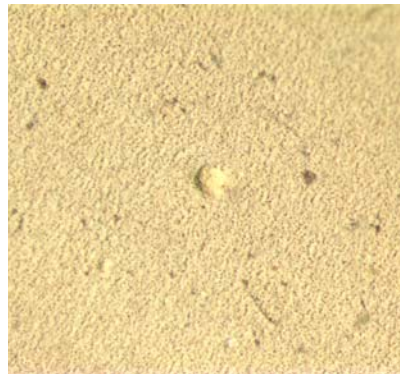
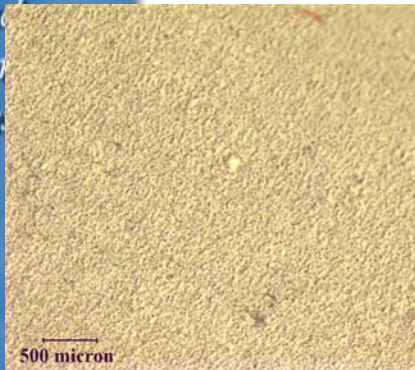
Pit Cavity Solids Analysis



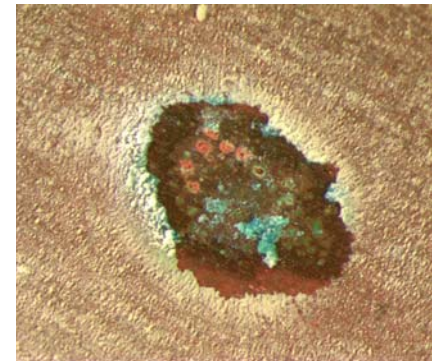
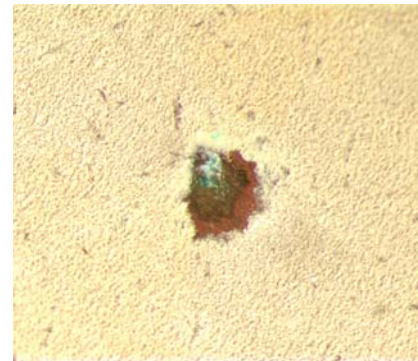
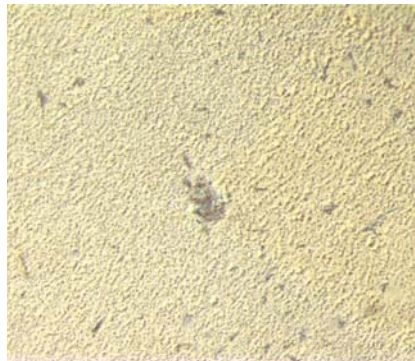
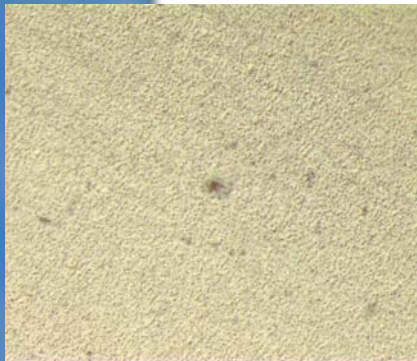
Pits are loosely packed with
cuprite crystals beneath the
permeable membrane



Pit Propagation Theory

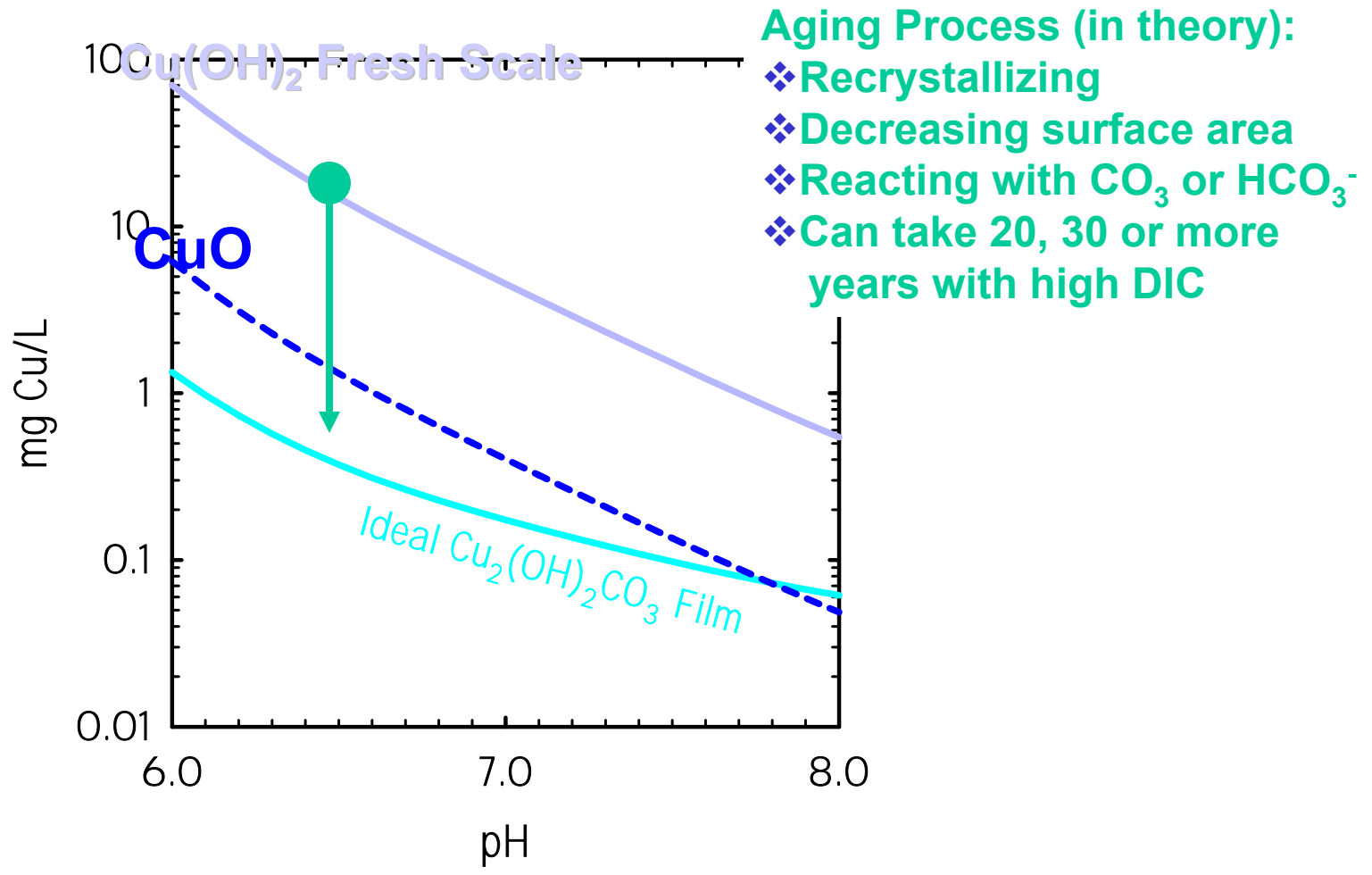


Particle deposition, particle growth, and corrosion cell formation



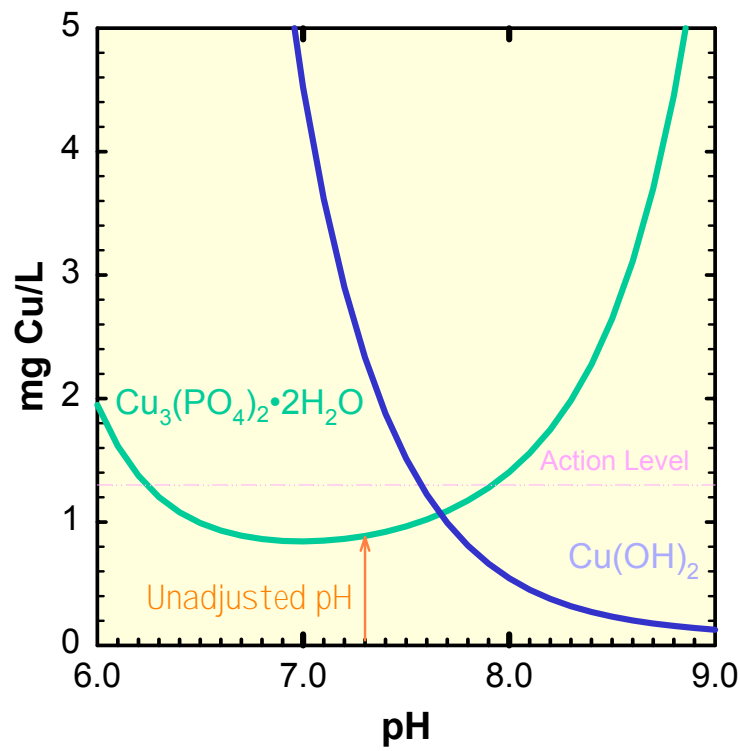
All pictures taken at same magnification

Evolution of Scale Model for High DIC, Low pH

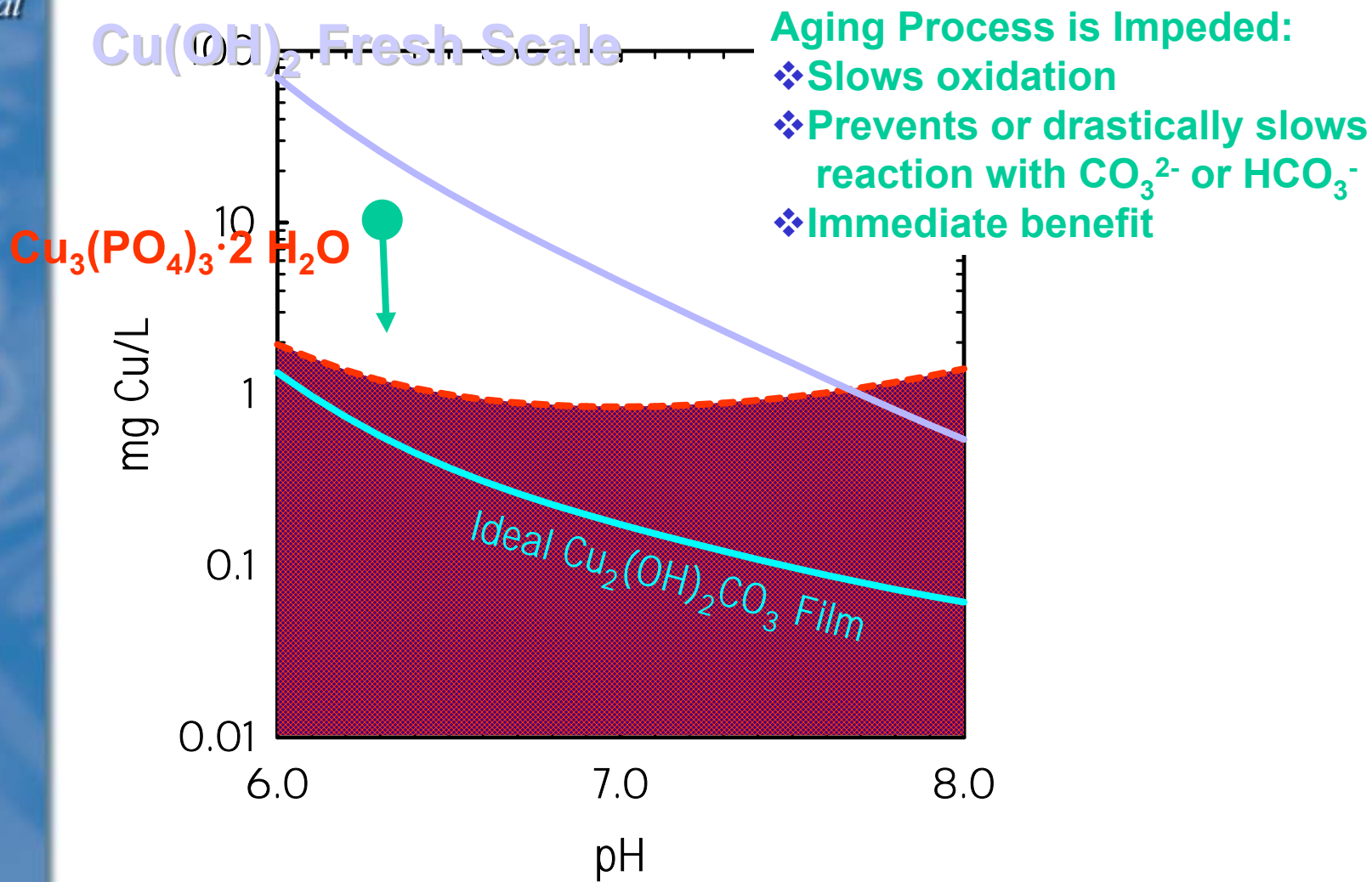


Theoretical Effect of Phosphate on Copper

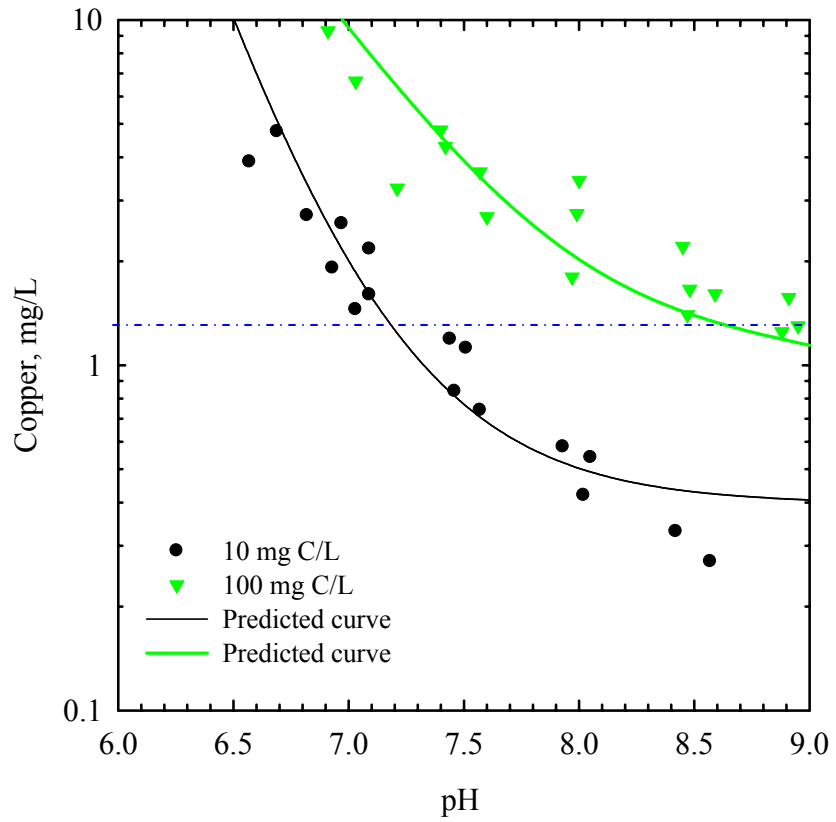
3.3 mg PO₄/L at DIC=63 mg C/L



Orthophosphate Effect on Scale Evolution at High DIC



Effect of Dissolved Inorganic Carbon on Copper Solubility



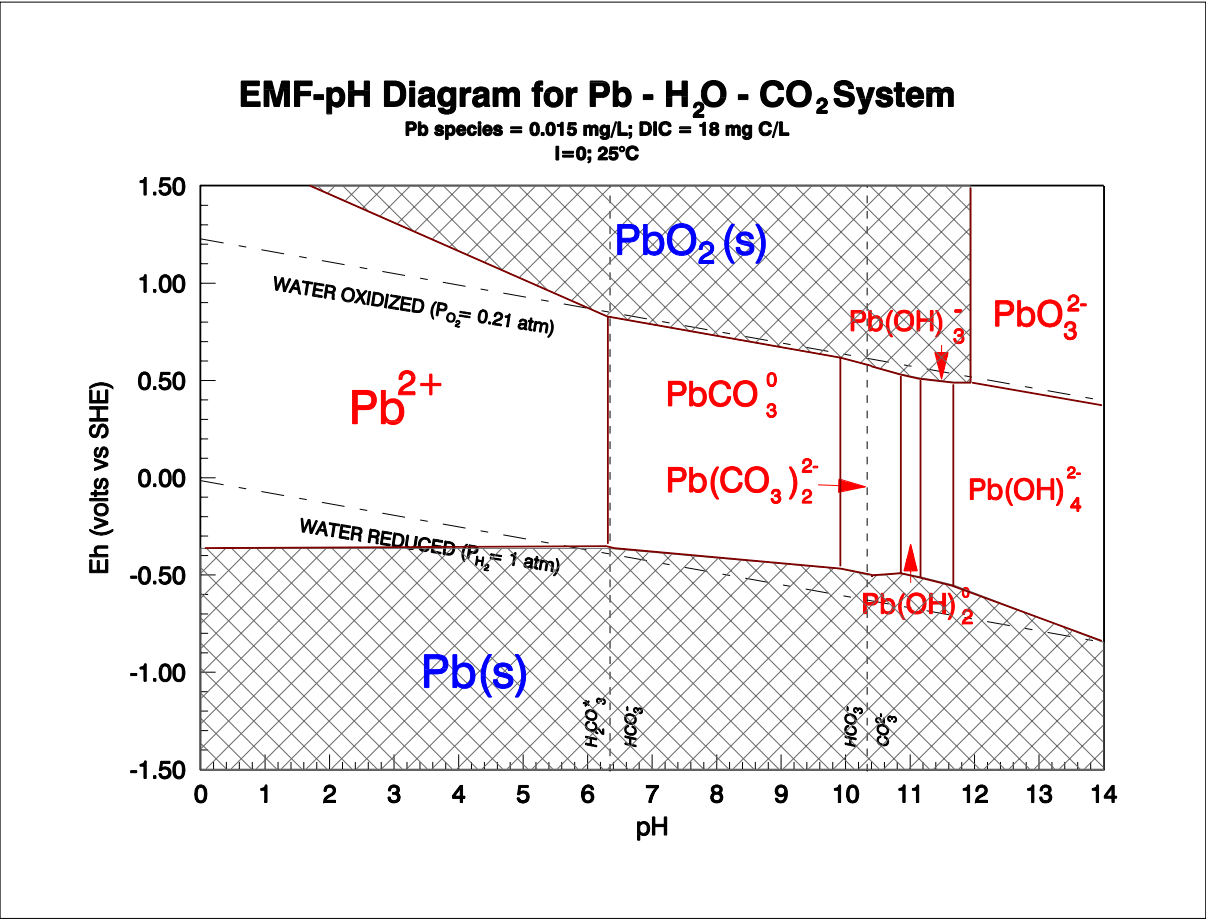
Pb Scales



Lead Corrosion (Solubility)

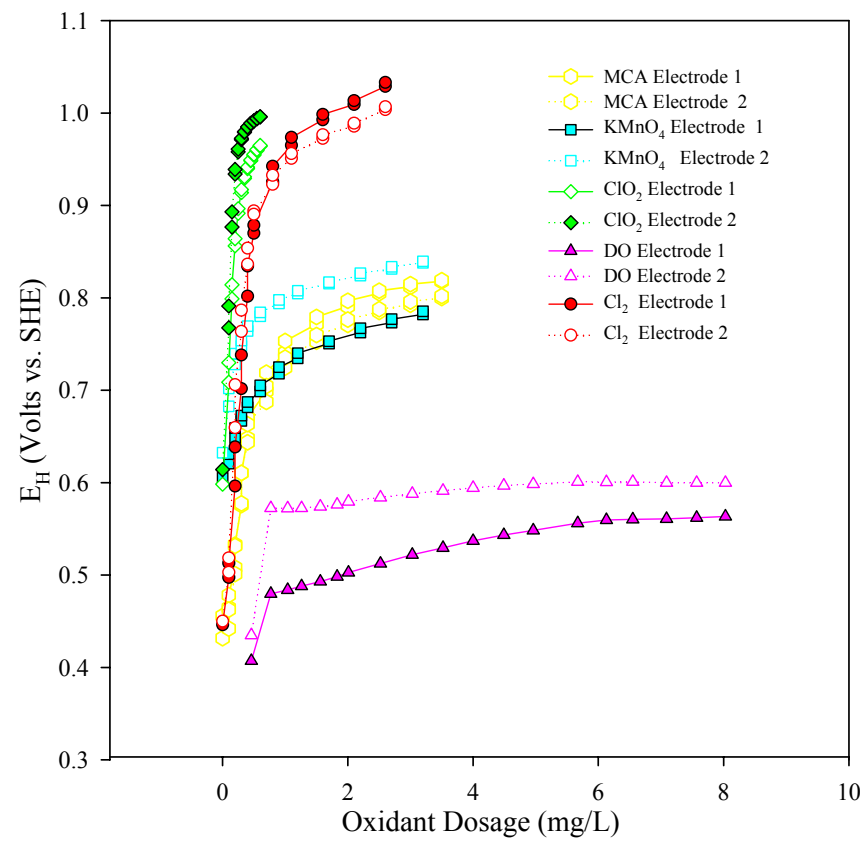
- Current basis for lead control strategies is based on Pb(II) chemistry.
- Relatively recently, Pb(IV) solids (PbO_2) have been found in a several distribution systems.
- Pb(IV) chemistry in water is relatively unknown (battery industry most applicable).

Lead Redox Chemistry



Redox Potential of Various Oxidants in Water at pH 7

10 mg C/L, 25°C



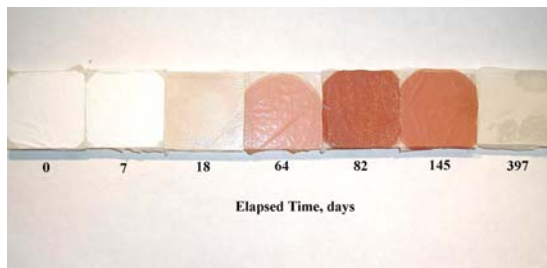
Implications of Pb(IV)

- Pb(IV) can form in drinking water DS under high and persistent Eh
- Based on limited data Pb(IV) is much less soluble than Pb(II)
- How does Pb(IV) form?
- How sensitive is PbO₂ to redox potential?

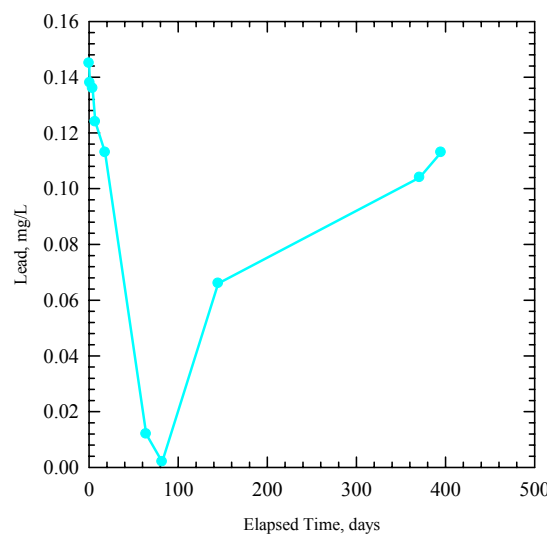
Bench Scale Studies

Lead Aging Study

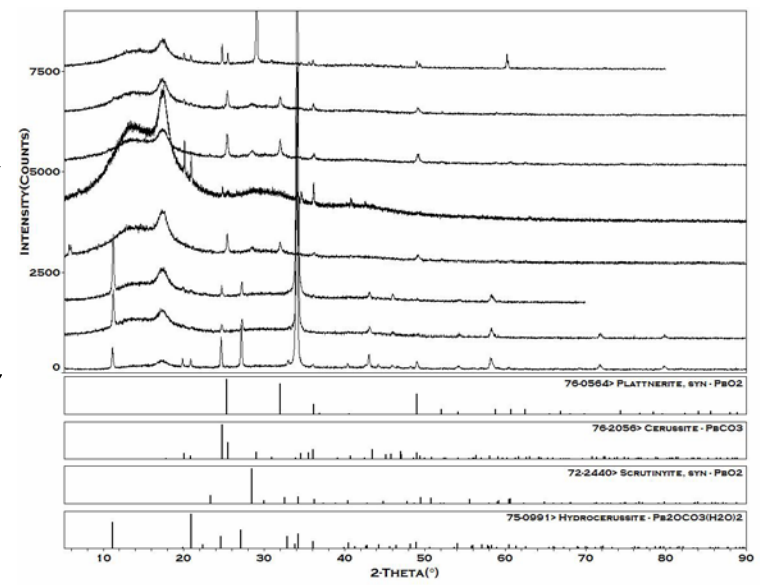
What is the Role of ORP on Lead Geochemistry in Water?



Appearance of lead solids with time



Corresponding change in soluble lead



Mineralogy of lead solids with time in well Chlorinated water.

Conclusions

- Lead and copper continues to be an area of concern and research interest
- Copper pitting leading to pinhole leaks is a complicated and under-reported problem
- Uniform copper corrosion issues include: role of phosphate, high alkalinity (DIC) water and aging of minerals
- Lead(II) versus Pb(IV) is the latest lead issue

Thank You